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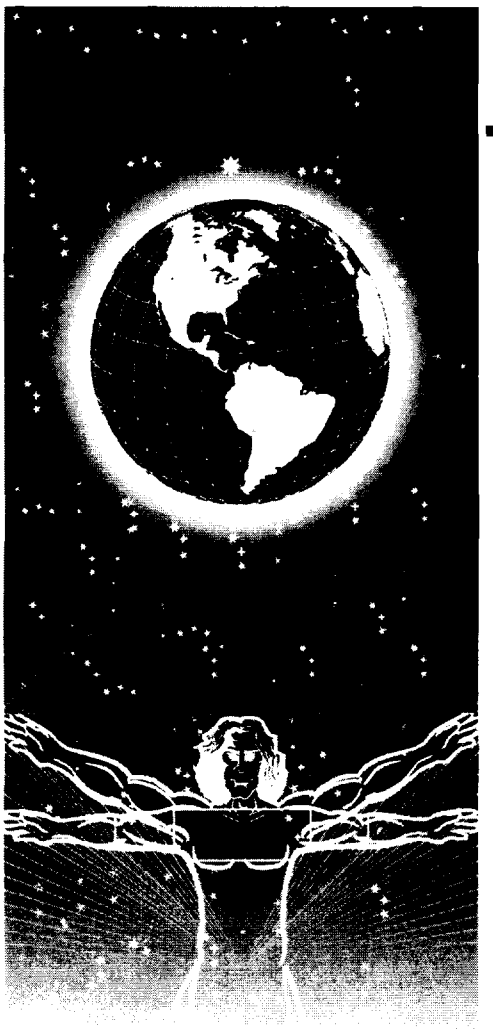

UNITED STATES AIR FORCE
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Human Health Risk Assessment, Pope Air Force Base, North Carolina (AMC)

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July 2000

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A human health risk assessment (HHRA) of total trihalomethanes (TTHM) was completed for Pope Air Force Base (Pope AFB). The purpose of this assessment was to quantify risks to military personnel and their families living on Pope AFB ingesting base supplied water with elevated levels of TTHM. HQ AMC/SGPB supported the base bioenvironmental engineer's request for AFIERA to perform a HHRA. The HHRA reviewed all potential exposure pathways of drinking water by comparing sample results to the USEPA Region 3 established standards. When an analytical result was identified as being above the USEPA Region 3 risk based concentration (RBC), it was identified as a chemical(s) of potential concern (COPC). There are 4 chemicals that sum together for the TTHM value. Of the 4 chemicals, 3 were above the RBC at least 10% of the total sampling history (May 1985- May 2000). Each COPC was statistically reviewed and risk estimates were calculated. This health risk assessment evaluated both cancer and non-cancer end points. Calculated risk for both cancer and non-cancer indicated that expected exposures are within the EPA guidelines. The risk calculations indicate personnel should not incur adverse health impact due to the TTHM in drinking water.

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EXECUTIVE SUMMARY

A human health risk assessment (HHRA) of total trihalomethanes (TTHM) was completed for Pope Air Force Base (Pope AFB). The purpose of this assessment is to quantify risks to military personnel and their families living on Pope AFB ingesting base supplied water with elevated levels of TTHM. HQ AMC/SGPB supported the base bioenvironmental engineer's request for AFIERA to perform a HHRA.

Pope AFB is located 12 miles northwest of Fayetteville, North Carolina. The base adjoins US Army Fort Bragg and provides intratheater airlift and close air support for airborne forces and other personnel, equipment, and supplies. Pope AFB purchases their drinking water from Fort Bragg. Fort Bragg has responsibility for supplying safe drinking water as defined by the US Environmental Protection Agency (USEPA) Safe Drinking Water Act (SDWA) and monitoring the drinking water for compliance with the SDWA and local and State requirements. Pope AFB is responsible to inform the base populace of any non-compliance status as well as an annual consumer confidence report (CCR) for the purchased water. Fort Bragg sampling data indicated that the TTHM level is currently exceeding the maximum contaminant level of 100 micro-grams per liter of water. The Air Force Institute for Environment, Safety and Occupational Health Risk Analysis (AFIERA) performed a narrow focused risk assessment for TTHM in the water system.

The HHRA reviewed all potential exposure pathways of drinking water by comparing sample results to the USEPA Region 3 established standards. When an analytical result was identified as being above the USEPA Region 3 risk based concentration (RBC), it was identified as a chemical(s) of potential concern (COPC). There are 4 chemicals that sum together for the TTHM value. Of the 4 chemicals, 3 were above the RBC at least 10% of the total sampling history (May 1985- May 2000). Each COPC was statistically reviewed and risk estimates were calculated.

This health risk assessment evaluated both cancer and non-cancer end points. Calculated risk for both cancer and non-cancer indicated that expected exposures are within the EPA guidelines. The risk calculations indicate personnel should not incur adverse health impact due to the TTHM in drinking water.

INTRODUCTION

Purpose

The purpose of this health risk assessment is to quantify risks to military personnel and their families living on Pope AFB from exposures to total trihalomethanes (TTHM) in the drinking water. HQ AMC/SGPB supported the base bioenvironmental engineer's request for a HHRA.

Background

Pope AFB is located 2 miles west of Spring Lake, NC and 12 miles northwest of Fayetteville, North Carolina. The main highways are I-95, Hwy 210, and Hwy 87. The base is surrounded by US Army Fort Bragg and provides intratheater airlift and close air support for airborne forces and other personnel, equipment, and supplies. Pope AFB purchases their drinking water from Fort Bragg.

Fort Bragg is responsible for supplying safe drinking water as defined by the US Environmental Protection Agency (USEPA) Safe Drinking Water Act (SDWA) and monitoring the drinking water for compliance with the SDWA and local and State requirements. Pope AFB is responsible to inform the base populace of non-compliance status with the drinking water. They are required to provide an annual consumer confidence report (CCR) for the purchased water.

Fort Bragg sampling data indicated that the TTHM level exceeds the maximum contaminant level of 100 micro-grams per liter of water (ug/L). The Air Force Institute for Environment, Safety and Occupational Health Risk Analysis (AFIERA) was requested to provide a focused risk assessment for TTHM in the water system.

Based on the report "Air Force Assignment Data Analysis Report" (AFIERA, 2000), the 95th percentile upper confidence level of time on station is 7.67 years for enlisted members and 4.18 years for officers. Based on this, we chose exposure duration of 8 years.

Climate

Pope AFB enjoys a moderate climate without marked seasons. May through September is typically hot and temperatures can reach 100°F accompanied with moderate to high relative humidity levels. Historical averages of the climatic conditions are shown in Table 1.

TABLE 1. Historical Average Climatic Conditions

	Average			
Season	**High (°F)**	**Low (°F)**	**Humidity**	**Precipitation**
Winter	54.3	32.7	61.3	3.5
Spring/Fall	70.7	46.3	56.3	3.3
Summer	85.6	65	64.4	4.7

RISK ASSESSMENT METHODOLOGY

We used existing US EPA risk assessment guidance for superfund (RAGS) as the framework for evaluating data quality, exposure intake, toxicity, and risk characterization. Our analysis is separated into four distinct phases and includes a discussion on the uncertainty and its effect on the risk estimate. Although these guidance documents have been written to address environmental cleanup, the approach is considered valid to assess exposure, toxicity, and risk at non-cleanup sites.

Data Collection and Evaluation

Data collection and evaluation answers the questions of what contaminants are present, where they are present, and in what concentrations. 43 MDOS/SGOAB provided 15 years of TTHM sampling data for Fort Bragg. The data was provided on an Excel spreadsheet with 4 to 5 sample locations per sample period (day). Over all there are 1176 data points with 294 for each of the 4 chemicals. These results were used to calculate excess lifetime cancer risk and non-cancer effects to personnel living on Pope AFB for an 8-year duration.

The results we reviewed were summary in nature and did not include data packages with holding times, chromatograms, quality control information, or practical quantification limits.
For the purposes of this assessment, we must assume that prior reviews have documented the data to be of adequate quality. The uncertainty of this data gap on the outcome is unknown.

The sample results were screened to identify contaminants of potential concern (COPC). During the screening process, the results were compared to the United States Environmental Protection Agency (USEPA), Region 3 Risk Based Concentration (RBC) values. Region 3 RBC values were used because US EPA Region 4 recommends using them for risk assessments in their region. This initial screening identified 3 COPC.

Each COPC was queried to determine the frequency (number of times it was sampled compared to the number of times it was above the RBC value). Contaminants with a frequency of less than 5 percent would be eliminated. Arguably, as stated in RAGS, using 5 percent with data sets of less than 20 samples automatically results in the inclusion of all data. All of the COPC were above the five percent threshold.

When a contaminant of potential concern was identified, all sample results for that contaminant were evaluated. Some of the sample results were less than the detection limit. In accordance with RAGS, sample results indicating less than the sample detection limit were modified to half of the detection value, and samples indicating non-detect were given half of the lowest detection level.

The contaminants were sorted by chemical. The results for each contaminant were then statistically analyzed to determine if the data distribution fit better to a normal or log normal distribution. The 95 percentile upper confidence limit (95% UCL) was calculated based on the type of best fit. The 95% UCL value was used as the (RME) concentration to derive risk

numbers. Whenever the 95% UCL exceeded the maximum sample result value, the maximum sample result was used as the RME. The central tendency (CT) values were also calculated to derive comparative risk numbers. The COPC are listed in Table 2.

TABLE 2. Chemicals of Potential Concern.

Num	CAS	COPC	RBC	Unit	Max	95% UCL	CT
1	75274	Bromodichloromethane	0.17	µg/L	102	21.6	4.783
2	75252	Bromoform	2.3	µg/L	1.4	Not Necessary	
3	124481	Chlorodibromomethane	0.13	µg/L	45.2	4.79	1.068
4	67663	Chloroform	0.15	µg/L	245.9	174.174	76.29

The data for this risk assessment is well established. TTHM samples were collected at least 4 times a year for the past 15 years. Good data collection increases the confidence of the risk estimation. All of the samples reviewed in this assessment were collected and analyzed by Fort Bragg and their laboratory of choice.

Trihalomethanes are produced from the reaction of chlorinated water with organic and inorganic material in the water. A more detailed discussion is provided under the toxicity section. A brief synopsis of each chemical is provided below.

Bromodichloromethane - Bromodichloromethane (BDCM) is currently used as a chemical intermediate for organic synthesis and as a laboratory reagent. It is commonly found as a by-product of water chlorination and may be found in drinking water and swimming pools. There is no human data for health effects from exposure to BDCM, but animal data suggests it may effect the liver and kidney.

Bromoform - Bromoform is used as a chemical intermediate in the synthesis of organic chemicals and pharmaceuticals. It is also used in polymer reactions in the vulcanization process of rubber and can be used for medicinal purposes. It is also a chlorination by-product and may be an indicator of organic activity in water. Bromoform can be toxic by all routes of exposure. Symptoms of acute exposure include severe irritation of the eyes, lacrimation, salivation, skin and respiratory tract irritation, headache, and dizziness. Chronic exposure may cause liver damage and memory loss.

Chlorodibromomethane - In the USA, chlorodibromomethane (CDBM) is currently produced in small amounts for laboratory use. Another source of CDBM is a by-product of water chlorination (drinking water disinfection). There were no studies on health effects from exposure to CDBM, but animal studies suggest toxicity to the liver and kidney. Inhaling high levels of CDBM can affect CNS activity.

Chloroform - Chloroform is used to manufacture other chemicals. It is released to the air and water through waste streams. Chloroform is also a by-product of water chlorination. Chloroform affects the CNS, liver, and kidneys. Acute exposures may result in fatigue, dizziness, and headache. Chloroform may have a possible link to colon and urinary cancer.

Exposure Assessment

Exposure assessment is the determination or estimation, qualitatively or quantitatively, of the magnitude, frequency, duration, and route of exposure. Exposure is defined as the contact of an organism with a chemical or physical agent.

The exposure assessment is a four-step process:

Step 1: Characterize the Exposure Setting
Step 2: Identify Exposure Pathways
Step 3. Quantify Exposure
Step 4. Verify Completed Pathway

Step 1. Characterize the Exposure Setting

The exposure setting for this assessment is a typical military installation where military and their dependents reside on base and receive their water from the base. Assumptions made for the exposure assessment include; base population drank 2 liters of plumbed water per day and took one shower/bath per day. Civilian employees (industrial workers) drank 1 liter of plumbed water per day and took one shower per day on base.

Based on the report "Air Force Assignment Data Analysis Report" (AFIERA, 2000), the 95th percentile upper confidence level of time on station is 7.67 years for enlisted members and 4.18 years for officers. Based on this, we chose exposure duration of 8 years. We assumed worst case for 350 days per year exposure, which is the EPA default value (EPA, 1989). Since this HRA is conservative with respect to approach and calculations, the EPA default value of 15 days away from the site is used in-lieu of more site-specific data that may be closer to 335 days accounting for annual leave. For industrial workers, we compared risks for 15, 20, 25, and 30 years of service.

Step 2. Identify Exposure Pathways

This assessment considered possible exposure pathways that included domestic uses of water – consumption and washing. The routes of exposure considered were ingestion, inhalation from showering, and dermal absorption from showering. No other pathways from water were included (washing clothes, flushing, and cooking).

Step 3. Quantify Exposure

A tiered approach to risk assessment was followed as shown in Figure 1. A simple screening was conducted comparing sample results to EPA Region 3 risk based concentration (RBC) values. EPA Region 3 RBC values were used to provide a consistent approach for all Southwest Asia Risk Assessments. Tier I screening indicated that only bromoform is below the RBC. COPC were further evaluated using USEPA Risk Assessment Guidance for Superfund Sites.

In order to quantify exposures, it is necessary to make assumptions and assign values to these assumptions. A USEPA risk assessment usually includes an estimation of intake based on both the average concentration and a concentration correlating to the 95th upper confidence level on the mean. Since the 95th UCL approach is more conservative, it was used to estimate intake. *This likely overestimated the risk.* Attachment 1 presents a summary of all the COPC (includes total number of analytes, frequency, media type, RBC value, max value, best fit determination of sample distribution as being normally or lognormally distributed -- determined by the D'Agostino's test for fit, and sampling information).

In the absence of site-specific data, USEPA recommends default values based on scientific studies and professional judgment. Table 3 provides the values that we used in the evaluation. We have designated each as either a site-specific (SS) value or USEPA default (EPA).

TABLE 3. Exposure Parameters for Inhalation and Ingestion

Land Use	Exposure Pathway	Daily Intake Rate	Exposure Frequency	Exposure Duration	Body Weight
Residential	Ingestion of Potable Water	2 liters (USEPA) 5 liters RSRE)	350 days/yr (USEPA)	8 years (SS)	70 kg (A) (USEPA) 15 Kg (C) (USEPA)
	Inhalation of Contaminants (Showering)	20 meters^3/day (USEPA)	350 days/yr (SS)	8 years (SS)	70 kg (A) (USEPA) 15 Kg (C) (USEPA)

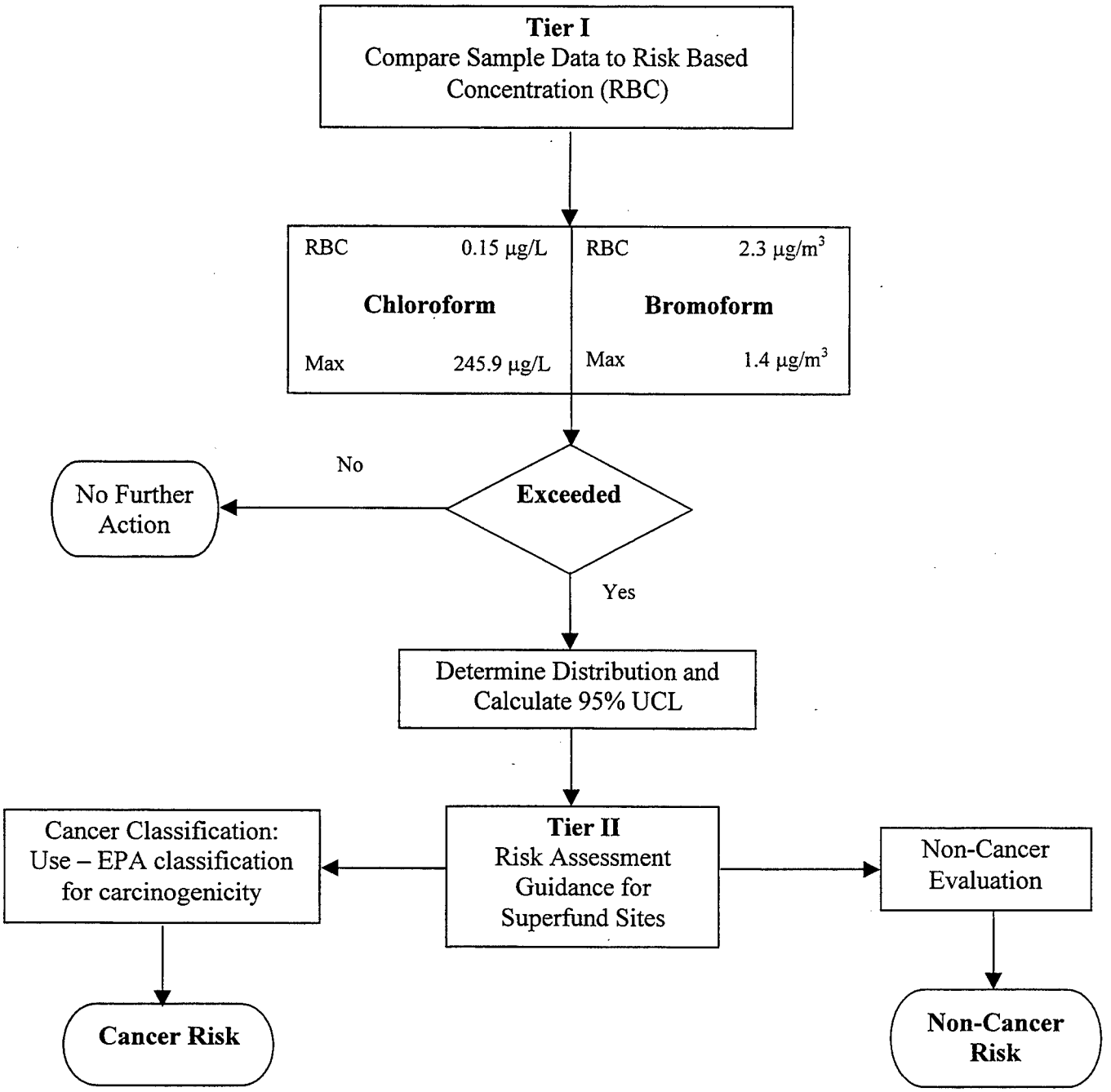
Note: (A) = Adult, (C) = Child

TABLE 4. Exposure Parameters for Dermal

For dermal absorption in a showering scenario, defaults are somewhat different. We used parameters for skin surface area and bath duration.

		Skin Surface Area			
Residential	Dermal Absorption (Showering)	23000 cm^2 (A) (USEPA) 7200 cm^2 (C) (USEPA)	350 days/yr (SS)	8 years (SS)	70 kg (A) (USEPA) 15 Kg (C) (USEPA)
		Bath Duration			
		0.2 hr (USEPA)			

Figure 1. Tiered Approach to Risk Assessment.



There are 3 basic equations used to calculate intake and dose: drinking water ingestion, drinking water – shower inhalation, and drinking water – shower dermal. The plumbed water is assumed to be from potable water sources only. The equations are presented below.

Equation 1 is used to calculate the average daily intake from ingestion of contaminants in the drinking water. The exposure assumption values used to calculate the average dose from ingestion of drinking water contaminants are shown in table 2. The central tendency (CT), or average ingestion rate was assumed to be 2 L/day, with a maximum ingestion rate of 5 L/day. The average ingestion rate was selected because it is the default long-term ingestion rate for adults, and is based on the average consumption rate of water for adults performing normal activities. The maximum ingestion rate was selected because it represents an increased consumption of water due to heavy activities/increased temperature during the workday.

Equation 1: Residential Exposure – Drinking Water, Ingestion

$$I = CW \times \left(\frac{CR \times EF \times ED}{BW} \right) \times \frac{1}{AT}$$

where:

I	=	intake (mg/kg body weight per day)
CW	=	Chemical concentration in water (ug/L)
CR	=	Contact rate (liters/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (usually expressed in years)
BW	=	Body weight (kg)
AT	=	Averaging time (in days; for carcinogens 70 years x 365 days/year, for non-carcinogens ED x 365 days/year)

Equation 2 is used to calculate the average daily intake from inhalation of volatilized airborne contaminants from plumbed water. The exposure assumption values used to calculate the average dose from airborne contaminants are shown in table 2.

Equation 2: Residential Exposure – Non-Potable Water, Showering -- Inhalation

$$I = CA \times \left(\frac{IR \times EF \times ED \times SD}{BW} \right) \times \frac{1}{AT}$$

where:

I	=	Intake (mg/kg [body weight] per day)
CA	=	Chemical concentration in air (mg/m3)
IR	=	Inhalation rate (m3/min)
EF	=	Exposure frequency (days/year)

ED = Exposure duration (usually expressed in years)
BW = Body weight (kg)
AT = Averaging time (in days; for carcinogens 70 years x 365 days/year, for non-carcinogens ED x 365 days/year)
SD = Shower duration (minutes)

Equation 3 is used to calculate the average daily dose resulting from dermal contact with plumbed water. The exposure assumption values used to calculate the average dose from airborne contaminants are shown in Table 3.

Equation 3: Residential Exposure – Non-Potable Water, Showering -- Dermal

$$AD = CW \times \left(\frac{SA \times pK \times ET \times EF \times ED \times CF}{BW} \right) \times \frac{1}{AT}$$

where:

AD = Absorbed Dose (mg/kg body weight per day)
CW = Chemical concentration in water (mg/L)
SA = Skin surface area available for contact (cm^2)
pK = Chemical-specific dermal permeability constant (cm/hr)
ET = Exposure time (hours/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (usually expressed in years)
CF = Volumetric conversion factor for water (1 liter/1000cm^3)
BW = Body weight (kg)
AT = Averaging time (in days; for carcinogens 70 years x 365 days/year, for non-carcinogens ED x 365 days/year)

Step 4. Verify Completed Pathway

The evaluation and verification of the pathway is difficult with the limited data provided. For simplicity, our assumption is that personnel living on base are consuming plumbed water and showering on base and therefore the exposure pathway is considered complete.

Toxicity Assessment

Disinfection of drinking water is one of the major public health advances in the 20th century. One hundred years ago, typhoid and cholera epidemics were common throughout American

cities and disinfection was a major factor in reducing these epidemics. However, the disinfectants themselves can react with naturally occurring materials in the water to form unintended organic and inorganic byproducts, which may pose health risks. Trihalomethanes (THM) are a group of four chemicals that are formed along with other disinfection byproducts. The trihalomethanes are chloroform, bromodichloromethane, chlorodibromomethane, and bromoform. EPA has published the Stage 1 Disinfectants/Disinfection Byproducts Rule to regulate total trihalomethanes (TTHM) at a maximum allowable annual average level of 80 parts per billion. This standard will replace the current standard of a maximum allowable annual average level of 100 parts per billion in December 2001 for large surface water public water systems. The standard will become effective for the first time in December 2003 for small surface water and all ground water systems such as Pope AFB.

Since the discovery of chlorination byproducts in drinking water in 1974, numerous toxicological studies have been conducted. These studies have shown several disinfection byproducts to be carcinogenic in laboratory. Some disinfection byproducts have also been shown to cause adverse reproductive or developmental effects in laboratory. However, there is considerable uncertainty involved in using the results of high-dose, toxicological studies of some byproducts occurring in disinfected drinking water to estimate the risk to humans from chronic exposure to low doses of these and other byproducts. In the area of epidemiology, a number of studies have been completed investigating the relationship between exposure to chlorinated surface water and cancer. Some have suggested an increased cancer risk to those exposed to chlorinated waters while others have demonstrated none. There remains considerable debate in the scientific community on the significance of these contradictory findings concerning chlorinated water and disinfection byproducts.

Toxicity Values

The toxicity assessment attempts to answer the questions "What are the main health effects?" and "At what concentrations might we see an effect?". The toxicity values are based on oral, dermal, and inhalation exposure pathways. Values for reference doses, reference concentrations, cancer slope and unit risk values have been derived from a variety of sources. The most acceptable and verifiable values are derived from US EPA's Integrated Risk Information System (IRIS).

To be cited in IRIS, there must exist a body of knowledge regarding a given chemical. For non-cancer studies, it is important to have chronic, multigenerational, developmental and reproductive studies. The use of established "no observed adverse effect level" (NOAEL) is the preferred method. In the absence of a NOAEL, the "lowest observed adverse effect level" (LOAEL) can be used. Human data usually take precedence over animal bioassay data. Cancer studies include human epidemiology studies, rodent bioassays, and vitro assays that might shed light on the mode of action for carcinogenesis. Non-verifiability in IRIS is usually due to a deficiency in the scientific data required for making quantitative analyses.

Toxicity values represent "safe" levels of exposure to avoid cancer and non-cancer effects. The primary source of for the values used come from IRIS. Where values for chemicals were not

found in IRIS, EPA Region III RBC tables were consulted. These tables are a compilation of both USEPA Health Effects Assessment Summary Table (HEAST) and recent EPA-NCEA (National Center for Environmental Assessment) provisional toxicity values. Table 5 identifies the COPC, the weight of evidence characterization of carcinogenicity, toxicity values used, and the source of value.

Risk Characterization

Risk characterization integrates information from the other components of the risk assessment and forms an overall conclusion about the risk. Steps for quantifying the carcinogenic risk or non-carcinogenic hazard quotient are applied to each exposure pathway and analyzed.

Carcinogenic Effects

For carcinogens, risk estimators are expressed as the excess incremental probability, above background cancer rates, of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen. US EPA guidance assumes a linear dose-response relationship due to the relatively low exposure levels found at Superfund sites; therefore, the slope factor is a constant, and the risk will be directly related to intake. Under this assumption, the linear low-dose equation for a single chemical is described below.

Equation 4: Carcinogenic Risk

$$[\text{Risk} = \text{LADD} \times \text{SF}]$$

Where:

Risk = A unit-less probability
LADD = Lifetime average daily dose over 70 years (mg/kg-day)
SF = Slope factor, the carcinogenic toxicity value $(\text{mg/kg-day})^{-1}$

Next, the risk calculated for each chemical of concern is summed together to generate an estimate of total risk per exposure pathway.

Equation 5: Total Risk

$$[\text{Total Risk} = Risk_1 + Risk_2 + Risk_3 + \ldots + Risk_i]$$

Where:

Total Risk = the total cancer risk, expressed as a unit-less probability
$Risk_i$ = the calculated risk for each chemical of concern

TABLE 5. Toxicity Factors for COPC

Reference Doses and Carcinogenic Potency Slope Factors

Sources: H = HEAST O = other
I = IRIS A = HEAST Alternate
E = EPA-NCEA provisional value W = Withdrawn from IRIS or HEAST

Contaminant	CAS	EPA Cancer Class.	Oral RfDo mg/kg/d	Source of data	Oral Slope Factor CSFo kg·d/mg	Source of data	Inhalation RfDi mg/kg/d	Source of data	Inhalation Slope Factor CSFi kg·d/mg	Source of data
Bromodichloromethane	75274	B2	2.00E-02	I	6.20E-02	I				
Chlorodibromomethane	124481	C	2.00E-02	I	8.40E-02	I				
Chloroform	67663	B2	1.00E-02	I	6.10E-03	I	8.60E-05	E	8.10E-02	I

Values for RfD, RfC, and slope factors derived from a number of sources:
I: US EPA Integrated Risk Information System.
n: US EPA National Center for Environmental Assessment (NCEA)
h: HEAST Tables (Health Effects Assessment Summary Tables
re: Route extrapolation

US EPA Cancer Classification Scheme:

A: Human carcinogen: sufficient evidence from epidemiologic studies to support a causal association between exposure and cancer.

B: Probable Human Carcinogen: weight of evidence of human carcinogenicity based on epidemiologic studies is limited; agents for which weight of evidence of carcinogenicity based on animal studies is sufficient.

Two subgroups:

B1: limited evidence of carcinogenicity from epidemiologic studies.

B2: Sufficient evidence from animal studies; inadequate evidence or no data from epidemiologic studies

C: Possible Human Carcinogen: limited evidence of carcinogenicity in animals in the absence of human data.

D: Not Classifiable as to Human Carcinogenicity: inadequate human and animal evidence of carcinogenicity or no data are available.

E: Evidence of Non-carcinogenicity for Humans: no evidence for carcinogenicity in at lease two adequate animal tests in different species or in both adequate epidemiologic and animal studies.

Reference Concentration (RfC): An estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious non-cancer effects during a lifetime.
Reference Dose (RfD): An estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.

Cancer Slope Factor (CSF): The slope of the dose-response curve in the low-dose region. When low-dose linearity cannot be assumed, the slope factor is the slope of the straight line from 0 dose (and 0 excess risk) to the dose at 1% excess risk. An upper bound on this slope is usually used instead of the slope itself. The units of the slope factor are usually expressed as 1/(mg/kg-day).

Noncarcinogenic Effects

The measure used to describe the potential for noncarcinogenic toxicity to occur in an individual is not expressed as a probability, but is a comparison of the exposure (intake) with a reference dose. This ratio of exposure to toxicity is called the noncancer hazard quotient.

Equation 6: Noncarcinogenic Hazard Quotient

$$\left[\text{Noncancer Hazard Quotient}^* = E/RfD \right]$$

Where:

E = Exposure level or chronic daily dose (CDD)
RfD = Reference dose

*E *And RfD must be expressed in the same units and represent the same exposure period.*

The RfD is the US EPA's preferred oral toxicity value for noncancer effects. It is defined as an estimate of a daily exposure level for the human population, including sensitive subpopulations (with an order of magnitude for uncertainty) that is likely to be without an appreciable risk of deleterious effects during a lifetime. If the exposure level exceeds the toxicity value (ratio greater than 1), there may be some concern for potential adverse health effects. The level of concern does not increase linearly as the RfD is approached or exceeded because RfDs do not have equal accuracy or precision nor are they based on the same severity of toxic effects.

Similar to calculating total risk, the total potential for noncancer effects is determined by summing the hazard quotients for each chemical of concern, resulting in a hazard index (also described in Exposure Assessment, Step 3).

Equation 7: Hazard Index

$$\left[HI^* = E_1/RfD_1 + E_2/RfD_2 + \ldots\ldots + E_i/RfD_i \right]$$

Where:

E_i = Exposure level (or intake) for the i^{th} toxicant
RfD_i = Reference dose for the i^{th} toxicant

*E *And RfD must be expressed in the same units and represent the same exposure period.*

If the hazard index exceeds unity (1), the analyst must closely examine the target organs involved. If different target organs are affected, the hazard index should be recalculated to group those chemicals that may elicit like responses.

Risk Calculations

Using the principles described above, the carcinogenic risks and non-cancer hazard indices were calculated accounting for exposures to drinking water ingestion, inhalation from showering, and dermal absorption from showering. The calculation for cancer risk is based on an 8-year exposure, but can be extrapolated to any period since the cancer risk is directly related to intake. For non-cancer effects, the hazard quotient is the same, regardless of duration.

In the Superfund program, USEPA tries to manage risks in the one in ten thousand to one in one million range. Below one in one million, the risk is considered negligible; above one in ten thousand, some remediation is usually required. The Agency's preference is for risk numbers to be near the more protective end of the range (one in one million). For Pope AFB, the cancer risk estimates for exposure to water are within the USEPA's target range. The cancer risks associated with exposure medium at Pope AFB, for an 8-year duration, for both 2-L/day and 5-L/Day ingestion of drinking water, and comparison of the RME and CT values are shown in Table 6.

For the purposes of this document, we have located Toxicity Values from the USEPA IRIS, Regional offices, EPA NCEA Health Effects Assessment Summary Tables (HEAST) and ATSDR. For non-cancer effects, the RfD, RfC, and MRLs are all derived in approximately the same way: NOAEL (or LOAEL) is determined (preferably from human data, but more usually from animal studies) and is divided by uncertainty factors. These uncertainty factors represent the uncertainty in extrapolating from animals to humans; from a LOAEL to a NOAEL; from subchronic to chronic studies; and to account for sensitive subpopulations.

TABLE 6. Associated Cancer Risk

Summary of Cancer Risks; Ingesting 2 and 5 Liters of Drinking Water per Day				
	RME		CT	
Exposure Route	*Cancer Risk 2 Liters/Day*	*Cancer Risk 5 Liters/Day*	*Cancer Risk 2 Liters/Day*	*Cancer Risk 5 Liters/Day*
Adult; Drinking Water -- Ingestion, 2 & 5 Liters per Day	8.78E-06	2.19E-05	2.67E-06	6.67E-06
Adult; Drinking Water -- Showering, Inhalation	7.61E-08	7.61E-08	2.22E-09	2.22E-09
Adult; Drinking Water -- Showering, Dermal	3.63E-06	3.63E-06	8.77E-07	8.77E-07
Totals for Adults	**1.25E-05**	**2.57E-05**	**3.55E-06**	**7.55E-06**

Summary of Cancer Risks; Ingesting 1 and 2 Liters of Drinking Water per Day				
	RME		CT	
Exposure Route	*Cancer Risk 1 Liters/Day*	*Cancer Risk 2 Liters/Day*	*Cancer Risk 1 Liters/Day*	*Cancer Risk 2 Liters/Day*
Child; Drinking Water -- Ingestion, 2 Liters per Day	2.05E-05	4.10E-05	6.22E-06	1.24E-05
Child; Drinking Water -- Showering, Dermal	5.08E-06	1.02E-05	1.23E-06	2.46E-06
Totals for Children	**2.56E-05**	**5.11E-05**	**7.45E-06**	**1.49E-05**

The non-cancer toxicity values for the chemicals of potential concern at Pope AFB are summarized in Table 7 as a Hazard Index value. A Hazard Index (HI) was calculated using the traditionally defined RfDs for each chemical. The HI for each exposure route and summed total are less than unity and therefore would not be evaluated any further within the United States. The HI for each exposure route is shown in Table 7 for adults and children.

TABLE 7. Systemic Hazard Quotient for Noncancer Risk - Adults

Summary of Noncancer Hazard Indices		
	RME	**CT**
Exposure Route	***NonCancer Systemic Hazard Index HI***	***NonCancer Systemic Hazard Index HI***
Adult; Drinking Water -- Ingestion, 2 Liters per Day	6.22E-05	2.41E-05
Adult; Drinking Water -- Showering, Inhalation	2.34E-08	1.83E-05
Adult; Drinking Water -- Showering, Dermal	8.18E-06	3.45E-06
Totals	**7.04E-05**	**4.59E-05**
Child; Drinking Water -- Ingestion, 2 Liters per Day	1.45E-04	5.63E-05
Child; Drinking Water -- Bathing, Dermal	1.15E-05	4.83E-06
Totals	**1.57E-04**	**6.11E-05**

Industrial workers (civilian employees) will likely have a longer exposure duration than that of the military population. In order to account for this longer exposure duration, a separate calculation was performed for the worker scenario on Pope AFB. The calculations are very similar to the resident scenario. The significant differences with the worker scenario are the longer exposure duration (up to 30 years), the decrease in water consumption (from 2 to 1), and the less frequent shower exposures. The cancer and noncancer results are provided in Table 8. All of the calculations are within the acceptable range.

TABLE 8. Industrial Worker Exposure Calculations

Summaries of Adult Cancer Risk and Noncancer Hazard Index; Industrial Worker				
	RME		CT	
Exposure Route	*Cancer Risk yrs*	*NonCancer Systemic Hazard Index HI*	*Cancer Risk yrs*	*NonCancer Systemic Hazard Index HI*
Adult; Drinking Water – Ingestion, 1 Liter per Day	3.92E-07	2.22E-05	1.19E-07	8.61E-06
Adult; Drinking Water – Showering, Inhalation	6.80E-09	1.86E-10	1.98E-10	1.31E-05
Adult; Drinking Water – Showering, Dermal	3.10E-07	5.61E-06	7.51E-08	2.36E-06
Total for 15 years of Exposure	**1.06E-05**	**4.17E-04**	**2.91E-06**	**3.61E-04**
Total for 20 years of Exposure	**1.42E-05**	**5.56E-04**	**3.89E-06**	**4.81E-04**
Total for 25 years of Exposure	**1.77E-05**	**6.95E-04**	**4.86E-06**	**6.01E-04**
Total for 30 years of Exposure	**2.13E-05**	**8.34E-04**	**5.83E-06**	**7.22E-04**

UNCERTAINTY

Risk assessments are estimations of what might occur under certain conditions, provided there is both a hazard present and exposure occurs. These estimations are based on data and assumptions that contain inherent uncertainties. Uncertainties may contribute to an overestimation or underestimation of risk, or the effect on the outcome may be unknown. These will be addressed according to the four-part risk assessment process.

Data Collection and Evaluation

Uncertainty is always an issue with environmental sampling, largely because of the potential for uneven distribution of chemicals in the environmental media over space and time. The sampling data analyzed to accomplish this risk assessment has uncertainties associated with it. There is no background information provided on the sampling data other than a location and a result. The assumption is that the samples taken on Fort Bragg are representative of expected water quality on Pope AFB. The actual numbers can be higher, lower, or the same.

With any risk assessment, the data needs to be representative of the environmental exposures associated with the site. The sample data appears to span the normal 4 quarters of the year and covers a 15 year period. This suggests the data is representative of the actual exposures associated with the sample locations. Data precision and accuracy are unknown.

Many of the sample results are reported as less than the detection limit. When converting the results that were less-than a detection limit value to an actual number (half of the detection limit), all of the sample analytes resulted as being above the RBC. This indicates the analytical detection limit was not low enough to be used in a risk-based analysis for the established RBC. This could result in over estimating the actual risk.

Exposure Assessment

The actual exposure to contaminants from showering and bathing are also unknown since the time and frequencies are assumptions. The actual amount of water ingested will also vary and more people are drinking more bottled water, which could lower the actual risk.

Showering is also a source of uncertainty. We have assumed inhalation of THMs while showering, but do not have measured data to support the concentrations we calculated using Henry's Law constants—the impact on the assessment is unknown. Dermal absorption also introduces uncertainty because we assumed the THMs will remain in the water to contact the skin, and then be absorbed into the body. However, because we have assumed volatilization previously, it is unlikely the concentrations we calculated would be achieved in both media. As a result, the risk is probably overestimated.

Toxicity Assessment

Toxicity values are based primarily on animal studies, where a LOAEL or NOAEL is generated experimentally in response to a known exposure over a defined period of time. Safety factors are then applied to the LOAEL or NOAEL to yield a reference dose (RfD, oral) or reference concentration (RfC, inhalation) that is considered the safe threshold for human exposure. Safety factors can range from 1 to 10,000, so there can be a large degree of uncertainty about the "safe dose" for humans. In general, these safety factors will lead to an overestimation of toxicity in humans, and therefore lead to an overestimation of the true risk or non-cancer hazard potential.

DISCUSSION

Personnel assigned to Pope AFB for up to 8 years should not have negative impact on their health based on TTHM in the drinking water. This HHRA is for both the carcinogenic and non-carcinogenic health risks to military and civilian personnel. The results for both are within the acceptable range considered safe by the USEPA. These risk estimates are based on very conservative estimates of exposure and toxicity and are likely to overestimate the actual risk.

Although the predicted health impact to base personnel is minimal, the data analyzed is at a screening level only. Recommendations for further evaluation are provided under the recommendation section.

It is important to understand that the toxicity values were established to protect the health of the most sensitive populations, for a 30 year exposure duration. This HHRA is for a military population, with a probable maximum duration of 8 years. As with most health impact, the toxicity of chemicals can be highly variable in individuals. Overall physical condition, chemical sensitivities, and diet all play a major role in physiological response to exposure. A more site-specific investigation can be accomplished to determine more realistic risks. As a next step, once site-specific information is obtained, a probabilistic risk assessment can be accomplished.

While showering, volatile chemicals have the potential to volatilize, aerosolize, and remain in the water. Separate calculations were used to estimate exposure for volatilization and dermal contact due to showering, and the aerosolization was ignored. The aerosolized route was ignored because the ingestion route was previously calculated and the droplets from aerosolization are normally large enough to ignore the inhalation route—which is captured for volatiles anyway.

RECOMMENDATIONS

1. A complete drinking water analysis should be accomplished to determine actual risks of exposure to the supplied water. The risk to base personnel for drinking the water is complex and TTHM probably represents only a percentage of the overall risk.

2. Coordinate with Fort Brag Preventive Medicine personnel for updates to the drinking water system. It is our understanding that Fort Brag has funding for modifying the water system.

3. Information in this report that is to be presented to the base population needs to be done in non-technical language. We encourage the advice of trained risk communicators to review your message before presenting it. AFIERA has several trained risk communicators and are willing to assist with finalizing your message.

CONCLUSIONS

The risk calculations indicate personnel should not incur adverse health impact due to the TTHM in drinking water. A tiered approach was utilized to perform this health risk assessment. The purpose was to evaluate potential health threats to personnel from trihalomethanes in the drinking water. The assessment looked at all potential exposure pathways. A more complete analysis of the water should be accomplished in the future to determine actual risk from the drinking water on Pope AFB.

The HRA reviewed all potential exposure pathways by comparing sample results to EPA established standards. When an analytical result was identified as being above the USEPA risk based concentration (RBC), it was identified as a chemical(s) of potential concern (COPC). Each COPC was statistically reviewed and risk estimates were calculated.

This health risk assessment utilized two different approaches for evaluating the risks for resident and industrial worker populations. A cancer and non-cancer risk assessment indicated that exposures are well below the recommended EPA guidelines for both populations.

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APPENDIX A

SUMMARY OF DATA

A summary of the data is presented in the following tables.

Human Health Risk Assessment
Pope Air Force Base (AMC)

Summary of Pope AFB TTHM Sample Results

Total Number of Results: **1176**

Total Number Exceeding RBC: **549**

Code	Type	Total	> RBC
BK	Blank	0	0
EX	Air-Ambient	0	0
GM	Grab - Bulk Material	0	0
GN	Grab - Water (Non-Potable)	0	0
GP	Grab - Water (Potable)	1176	549

Assumptions:

Adult Population (No Children or Elderly)

Exposure Duration: 2 yrs

Water Consumption: 2 - 5 L

Body Weight: 70 kgs

Use other EPA Defaults

Total Number of COPC Analytes: **1176**

Total Number Exceeding RBC: **549**

A = Air P = Potable Water

N = Non-potable Water

Num	CAS	COPC	Total	> RBC	Freq	Media	RBC	Unit	Max	95% UCL	CT	Best Fit	Unique Samp Days	Inclusive Dates For Sample Collectioin
1	75274	Bromodichloromethane	294	248	84%	P	0.17	µg/L	102	21.6	4.783	L	62	20-May-85 - 16-May-00
2	75252	Bromoform	294	0	0%	P	2.3	µg/L	1.4	Not Necessary				-
3	124481	Chlorodibromomethane	294	30	10%	P	0.13	µg/L	45.2	4.79	1.068	L	62	20-May-85 - 16-May-00
4	67663	Chloroform	294	271	92%	P	0.15	µg/L	245.9	174.174	76.29	N	62	20-May-85 - 16-May-00

Summary of Adult Cancer Risks and Noncancer Hazard Indices; 2 Liters Water ingested per Day				
	RME		**CT**	
Exposure Route	***Cancer Risk 8 yrs***	***NonCancer Systemic Hazard Index HI***	***Cancer Risk 8 yrs***	***NonCancer Systemic Hazard Index HI***
Adult; Drinking Water -- Ingestion, 2 Liters per Day	8.78E-06	6.22E-05	2.67E-06	2.41E-05
Adult; Drinking Water -- Showering, Inhalation	7.61E-08	2.34E-08	2.22E-09	1.83E-05
Adult; Drinking Water -- Showering, Dermal	3.63E-06	8.18E-06	8.77E-07	3.45E-06
Totals	**1.25E-05**	**7.04E-05**	**3.55E-06**	**4.59E-05**

Summary of Child Cancer Risks and Noncancer Hazard Indices; 2 Liters Water ingested per Day				
	RME		**CT**	
Exposure Route	***Cancer Risk 8 yrs***	***NonCancer Systemic Hazard Index HI***	***Cancer Risk 8 yrs***	***NonCancer Systemic Hazard Index HI***
Child; Drinking Water -- Ingestion, 1 Liters per Day	2.05E-05	1.45E-04	6.22E-06	5.63E-05
Child; Drinking Water -- Showering, Dermal	5.08E-06	1.15E-05	1.23E-06	0.00E+00
Totals	**2.56E-05**	**1.57E-04**	**7.45E-06**	**5.63E-05**

Summary of Cancer Risks; Ingesting 2 and 5 Liters of Drinking Water per Day

	RME		CT	
Exposure Route	***Cancer Risk 2 Liters/Day***	***Cancer Risk 5 Liters/Day***	***Cancer Risk 2 Liters/Day***	***Cancer Risk 5 Liters/Day***
Adult; Drinking Water -- Ingestion, 2 & 5 Liters per Day	8.78E-06	2.19E-05	2.67E-06	6.67E-06
Adult; Drinking Water -- Showering, Inhalation	7.61E-08	7.61E-08	2.22E-09	2.22E-09
Adult; Drinking Water -- Showering, Dermal	3.63E-06	3.63E-06	8.77E-07	8.77E-07
Totals for Adults	**1.25E-05**	**2.57E-05**	**3.55E-06**	**7.55E-06**

Summary of Cancer Risks; Ingesting 1 and 2 Liters of Drinking Water per Day

	RME		CT	
Exposure Route	***Cancer Risk 1 Liters/Day***	***Cancer Risk 2 Liters/Day***	***Cancer Risk 1 Liters/Day***	***Cancer Risk 2 Liters/Day***
Child; Drinking Water -- Ingestion, 2 Liters per Day	2.05E-05	4.10E-05	6.22E-06	1.24E-05
Child; Drinking Water -- Showering, Dermal	5.08E-06	1.02E-05	1.23E-06	2.46E-06
Totals for Children	**2.56E-05**	**5.11E-05**	**7.45E-06**	**1.49E-05**

Summary of Noncancer Hazard Indices		
	RME	**CT**
Exposure Route	***NonCancer Systemic Hazard Index HI***	***NonCancer Systemic Hazard Index HI***
Adult; Drinking Water -- Ingestion, 2 Liters per Day	6.22E-05	2.41E-05
Adult; Drinking Water -- Showering, Inhalation	2.34E-08	1.83E-05
Adult; Drinking Water -- Showering, Dermal	8.18E-06	3.45E-06
Totals	**7.04E-05**	**4.59E-05**

Summary of Noncancer Hazard Indices		
	RME	**CT**
Exposure Route	***NonCancer Systemic Hazard Index HI***	***NonCancer Systemic Hazard Index HI***
Child; Drinking Water -- Ingestion, 2 Liters per Day	1.45E-04	5.63E-05
Child; Drinking Water -- Showering, Dermal	1.15E-05	4.83E-06
Totals	**1.57E-04**	**6.11E-05**

Reference Doses and Carcinogenic Potency Slope Factors

~~Sources:~~ H = HEAST O = other

I = IRIS A = HEAST Alternate

E = EPA-NCEA provisional value W = Withdrawn from IRIS or HEAST

Contaminant	*CAS*	*EPA Cancer Class.*	*Oral RfDo* mg/kg/d	*Source of data*	*Oral Slope Factor CSFo* kg·d/mg	*Source of data*	*Inhalation RfDi* mg/kg/d	*Source of data*	*Inhalation Slope Factor CSFi* kg·d/mg	*Source of data*
Bromodichloromethane	75274	B2	2.00E-02	I	6.20E-02	I				
Chlorodibromomethane	124481	C	2.00E-02	I	8.40E-02	I				
Chloroform	67663	B2	1.00E-02	I	6.10E-03	I	8.60E-05	E	8.10E-02	I

APPENDIX B

RISK CALCULATION TABLES

The risk calculations used for this HRA are presented in the following tables.

Human Health Risk Assessment
Pope Air Force Base (AMC)

Adult Resident Drinking Water Ingestion

Daily Dose (LADD or CDD) = (RME or CT Conc. x IR x EF x ED) / (BW x AT)
Carcinogenic risk = LADD x Slope Factor
Hazard Quotient = CDD / Reference Dose

Contaminant	*RME Conc. mg/L*	*Lifetime Average Daily Dose mg/kg/d*	*Chronic Daily Dose mg/kg/d*	*Cancer Slope Factor CSFo kg·d/mg*	*Refernce Dose RfDo mg/kg/d*	*Lifetime Cancer Risk*	*Systemic Hazard Quotient*
Bromodichloromethane	2.16E-02	**6.76E-05**	**5.92E-04**	6.20E-02	2.00E-02	4.19E-06	1.18E-05
Chlorodibromomethane	4.79E-03	**1.50E-05**	**1.31E-04**	8.40E-02	2.00E-02	1.26E-06	2.62E-06
Chloroform	1.74E-01	**5.45E-04**	**4.77E-03**	6.10E-03	1.00E-02	3.33E-06	4.77E-05

Description	Units	Value	Rationale (Source)
RME Concentration	*mg/L*	listed	*95% Upper Confidence Limit or Maximium Detect Value*
Ingestion rate	*L/d*	**2**	*Site Specific Parameter*
Exposure frequency	*d/y*	**350**	*Site Specific Parameter*
Exposure duration	*y*	**8**	*Site Specific Parameter*
Body weight	*kg*	**70**	*Adult body weight, Convention; (USEPA 1991)*
Averaging time	*d*	**25550**	*Carcinogenic effects; (USEPA 1989)*
Averaging time	*d*	**2920**	*Noncarcinogenic effects; (USEPA 1989)*

Contaminant	*CT Conc. mg/L*	*Lifetime Average Daily Dose mg/kg/d*	*Chronic Daily Dose mg/kg/d*	*Cancer Slope Factor CSFo kg·d/mg*	*Refernce Dose RfDo mg/kg/d*	*Lifetime Cancer Risk*	*Systemic Hazard Quotient*
Bromodichloromethane	4.78E-03	**1.50E-05**	**1.31E-04**	6.20E-02	2.00E-02	9.29E-07	2.62E-06
Chlorodibromomethane	1.07E-03	**3.34E-06**	**2.93E-05**	8.40E-02	2.00E-02	2.81E-07	5.85E-07
Chloroform	7.63E-02	**2.39E-04**	**2.09E-03**	6.10E-03	1.00E-02	1.46E-06	2.09E-05

Adult Resident Showering Inhalation.

Daily Dose (LADD or CDD) = (RME or CT Conc. x IR x EF x ED) / (BW x AT)
Carcinogenic risk = LADD x Slope Factor
Hazard Quotient = CDD / Reference Dose

Contaminant	RME Avg. Air Conc. in Shower mg/m3	Lifetime Average Daily Dose mg/kg/d	Chronic Daily Dose mg/kg/d	Cancer Slope Factor	Refernce Dose	Lifetime Cancer Risk	Systemic Hazard Quotient
Bromodichloromethane	2.83E-01	**9.24E-05**	**3.01E-08**				
Chlorodibromomethane	5.19E-02	**1.69E-05**	**5.52E-09**				
Chloroform	2.71E+00	**8.85E-04**	**2.89E-07**	8.60E-05	8.10E-02	7.61E-08	2.34E-08

Description	Units	Value	Rationale (Source)
RME Concentration	*mg/L*	listed	*95% Upper Confidence Limit or Maximium Detect Value*
Inhalation rate	*m3/min*	**0.01389**	*Default (USEPA 1991)*
Exposure frequency	*d/y*	**350**	*Site Specific Parameter*
Exposure duration	*y*	**8**	*Site Specific Parameter*
Body weight	*kg*	**70**	*Adult body weight, Convention; (USEPA 1991)*
Averaging time carc.	*d*	**25550**	*Carcinogenic effects; (USEPA 1989)*
Averaging time ncarc.	*d*	**2920**	*Noncarcinogenic effects; (USEPA 1989)*
Shower duration	*min/d*	**15**	

Contaminant	CT Avg. Air Conc. in Shower mg/m3	Lifetime Average Daily Dose mg/kg/d	Chronic Daily Dose mg/kg/d	Cancer Slope Factor	Refernce Dose	Lifetime Cancer Risk	Systemic Hazard Quotient
Bromodichloromethane	6.27E-02	**1.36E-06**	**1.19E-05**				
Chlorodibromomethane	1.16E-02	**2.51E-07**	**2.20E-06**				
Chloroform	1.19E+00	**2.58E-05**	**2.26E-04**	8.60E-05	8.10E-02	2.22E-09	1.83E-05

Adult Resident Drinking Water Dermal Contact

Daily Dose (LADD or CDD) = (RME or CT Conc. x SA x pK x ET x EF x ED x 1E-3 l/ml) / (BW x AT)
Carcinogenic risk = LADD x Slope Factor
Hazard Quotient = CDD / Reference Dose

Contaminant	*RME Conc. mg/L*	*Dermal Permeab. Coeff. cm/h*	*Lifetime Average Daily Dose mg/kg/d*	*Chronic Daily Dose mg/kg/d*	*Cancer Slope Factor*	*Refernce Dose*	*Lifetime Cancer Risk*	*Systemic Hazard Quotient*
Bromodichloromethane	2.16E-02	2.00E-02	5.35E-06	4.68E-05	6.00E-01	9.00E-03	3.21E-06	4.22E-07
Chlorodibromomethane	4.79E-03	2.00E-02	1.19E-06	1.04E-05	6.20E-02	2.00E-02	7.36E-08	2.08E-07
Chloroform	1.74E-01	2.00E-02	4.32E-05	3.78E-04	7.90E-03	2.00E-02	3.41E-07	7.55E-06

Description	Units	Value	Rationale (Source)
RME Concentration	*mg/L*	listed	*95% Upper Confidence Limit or Maximium Detect Value*
Dermal Perm Coeff	*cm/h*	listed	*Table 5-8, Dermal Exposure Assessment (USEPA 1992)*
Surface area	*cm3*	**23000**	*Adult skin surface area, Convention; (USEPA 1991)*
Exposure frequency	*d/y*	**365**	*Site Specific Parameter*
Exposure duration	*y*	**8**	*Site Specific Parameter*
Body weight	*kg*	**70**	*Adult body weight, Convention; (USEPA 1991)*
Averaging time carc.	*d*	**25550**	*Carcinogenic effects; (USEPA 1989)*
Averaging time ncarc.	*d*	**2920**	*Noncarcinogenic effects; (USEPA 1989)*
Bath duration	*h/d*	**0.33**	*(USEPA 1992)*

Contaminant	*CT Conc. mg/L*	*Dermal Permeab. Coeff. cm/h*	*Lifetime Average Daily Dose mg/kg/d*	*Chronic Daily Dose mg/kg/d*	*Cancer Slope Factor*	*Refernce Dose*	*Lifetime Cancer Risk*	*Systemic Hazard Quotient*
Bromodichloromethane	4.78E-03	2.00E-02	1.19E-06	1.04E-05	6.00E-01	9.00E-03	7.11E-07	9.34E-08
Chlorodibromomethane	1.07E-03	2.00E-02	2.65E-07	2.32E-06	6.20E-02	2.00E-02	1.64E-08	4.63E-08
Chloroform	7.63E-02	2.00E-02	1.89E-05	1.65E-04	7.90E-03	2.00E-02	1.49E-07	3.31E-06

Adult Resident Showering -- Calculated Air Exposure Concentrations

Contaminant	RME Conc. mg/L	Mol. Wt. g/mol	Henry's Constant atm-m3/mol	Kl cm/h	Kg cm/h	Overall Trans. Coeff. KL cm/h	Temp-adj. Trans. Coeff. KaL cm/h	Conc. leaving H2O Cwd mg/l	VOC Gener. Rate S mg/m3-min	Air Conc. at Shower End mg/m3	Avg. Air Conc. in Shower mg/m3
Bromodichloromethane	2.16E-02	1.69E+02	2.41E-03	1.02E+01	9.80E+02	9.25E+00	1.24E+01	7.31E-03	5.04E-02	5.48E-01	2.83E-01
Chlorodibromomethane	4.79E-03	2.08E+02	9.90E-04	9.19E+00	8.82E+02	7.34E+00	9.83E+00	1.34E-03	9.23E-03	1.00E-01	5.19E-02
Chloroform	1.74E-01	1.19E+02	4.60E-03	1.21E+01	1.16E+03	1.15E+01	1.54E+01	7.00E-02	4.83E-01	5.25E+00	2.71E+00

Description	Units	Value	Rationale (Source)
L-phase t.c. CO2	cm/h	20	
G-phase t.c. H2O	cm/h	3000	
Water visc. at 20C	cp	1.002	
Water visc. at 45C	cp	0.596	
Shower temp	K	318	
Droplet diameter	mm	1	
Drop time	s	2	
Shower flow rate	L/min	20	
Shower stall volume	m3	2.9	
Shower duration	min	12	
Air exchange rate	min-1	0.0166667	(RANGE: .5 TO 1.5 PER HOUR)

Contaminant	CT Conc. mg/L	Mol. Wt. g/mol	Henry's Constant atm-m3/mol	Kl cm/h	Kg cm/h	Overall Trans. Coeff. KL cm/h	Temp-adj. Trans. Coeff. KaL cm/h	Conc. leaving H2O Cwd mg/l	VOC Gener. Rate S mg/m3-min	Air Conc. at Shower End mg/m3	Avg. Air Conc. in Shower mg/m3
Bromodichloromethane	4.78E-03	1.69E+02	2.41E-03	1.02E+01	9.80E+02	9.25E+00	1.24E+01	1.62E-03	1.12E-02	1.21E-01	6.27E-02
Chlorodibromomethane	1.07E-03	2.08E+02	9.90E-04	9.19E+00	8.82E+02	7.34E+00	9.83E+00	2.98E-04	2.06E-03	2.24E-02	1.16E-02
Chloroform	7.63E-02	1.19E+02	4.60E-03	1.21E+01	1.16E+03	1.15E+01	1.54E+01	3.07E-02	2.12E-01	2.30E+00	1.19E+00

Adult Resident Drinking Water Ingestion

Daily Dose (LADD or CDD) = (RME or CT Conc. x IR x EF x ED) / (BW x AT)
Carcinogenic risk = LADD x Slope Factor
Hazard Quotient = CDD / Reference Dose

Contaminant	*RME Conc. mg/L*	*Lifetime Average Daily Dose mg/kg/d*	*Chronic Daily Dose mg/kg/d*	*Cancer Slope Factor CSFo kg·d/mg*	*Refernce Dose RfDo mg/kg/d*	*Lifetime Cancer Risk*	*Systemic Hazard Quotient*
Bromodichloromethane	2.16E-02	**1.58E-04**	**1.38E-03**	6.20E-02	2.00E-02	9.78E-06	2.76E-05
Chlorodibromomethane	4.79E-03	**3.50E-05**	**3.06E-04**	8.40E-02	2.00E-02	2.94E-06	6.12E-06
Chloroform	1.74E-01	**1.27E-03**	**1.11E-02**	6.10E-03	1.00E-02	7.76E-06	1.11E-04

Description	Units	Value	Rationale (Source)
RME Concentration	*mg/L*	listed	*95% Upper Confidence Limit or Maximium Detect Value*
Ingestion rate	*L/d*	**1**	*Site Specific Parameter*
Exposure frequency	*d/y*	**350**	*Site Specific Parameter*
Exposure duration	*y*	**8**	*Site Specific Parameter*
Body weight	*kg*	**15**	*Child body weight, Convention; (USEPA 1991)*
Averaging time	*d*	**25550**	*Carcinogenic effects; (USEPA 1989)*
Averaging time	*d*	**2920**	*Noncarcinogenic effects; (USEPA 1989)*

Contaminant	*CT Conc. mg/L*	*Lifetime Average Daily Dose mg/kg/d*	*Chronic Daily Dose mg/kg/d*	*Cancer Slope Factor CSFo kg·d/mg*	*Refernce Dose RfDo mg/kg/d*	*Lifetime Cancer Risk*	*Systemic Hazard Quotient*
Bromodichloromethane	4.78E-03	**3.49E-05**	**3.06E-04**	6.20E-02	2.00E-02	2.17E-06	6.12E-06
Chlorodibromomethane	1.07E-03	**7.80E-06**	**6.83E-05**	8.40E-02	2.00E-02	6.55E-07	1.37E-06
Chloroform	7.63E-02	**5.57E-04**	**4.88E-03**	6.10E-03	1.00E-02	3.40E-06	4.88E-05

Child Resident Drinking Water Dermal Contact

Daily Dose (LADD or CDD) = (RME or CT Conc. x SA x pK x ET x EF x ED x 1E-3 l/ml) / (BW x AT)
Carcinogenic risk = LADD x Slope Factor
Hazard Quotient = CDD / Reference Dose

Contaminant	*RME Conc. mg/L*	*Dermal Permeab. Coeff. cm/h*	*Lifetime Average Daily Dose mg/kg/d*	*Chronic Daily Dose mg/kg/d*	*Cancer Slope Factor*	*Refernce Dose*	*Lifetime Cancer Risk*	*Systemic Hazard Quotient*
Bromodichloromethane	2.16E-02	2.00E-02	7.50E-06	6.56E-05	6.00E-01	9.00E-03	4.50E-06	5.91E-07
Chlorodibromomethane	4.79E-03	2.00E-02	1.66E-06	1.46E-05	6.20E-02	2.00E-02	1.03E-07	2.91E-07
Chloroform	1.74E-01	2.00E-02	6.05E-05	5.29E-04	7.90E-03	2.00E-02	4.78E-07	1.06E-05

Description	Units	Value	Rationale (Source)
RME Concentration	*mg/L*	listed	*95% Upper Confidence Limit or Maximium Detect Value*
Dermal Perm Coeff	*cm/h*	listed	*Table 5-8, Dermal Exposure Assessment (USEPA 1992)*
Surface area	*cm3*	**7200**	*Adult skin surface area, Convention; (USEPA 1991)*
Exposure frequency	*d/y*	**350**	*Site Specific Parameter*
Exposure duration	*y*	**8**	*Site Specific Parameter*
Body weight	*kg*	**15**	*Adult body weight, Convention; (USEPA 1991)*
Averaging time carc.	*d*	**25550**	*Carcinogenic effects; (USEPA 1989)*
Averaging time ncarc.	*d*	**2920**	*Noncarcinogenic effects; (USEPA 1989)*
Bath duration	*h/d*	**0.33**	*(USEPA 1992)*

Contaminant	*CT Conc. mg/L*	*Dermal Permeab. Coeff. cm/h*	*Lifetime Average Daily Dose mg/kg/d*	*Chronic Daily Dose mg/kg/d*	*Cancer Slope Factor*	*Refernce Dose*	*Lifetime Cancer Risk*	*Systemic Hazard Quotient*
Bromodichloromethane	4.78E-03	2.00E-02	1.66E-06	1.45E-05	6.00E-01	9.00E-03	9.96E-07	1.31E-07
Chlorodibromomethane	1.07E-03	2.00E-02	3.71E-07	3.24E-06	6.20E-02	2.00E-02	2.30E-08	6.49E-08
Chloroform	7.63E-02	2.00E-02	2.65E-05	2.32E-04	7.90E-03	2.00E-02	2.09E-07	4.64E-06

Industrial Worker Drinking Water Ingestion

Daily Dose (LADD or CDD) = (RME or CT Conc. x IR x EF x ED) / (BW x AT)
Carcinogenic risk = LADD x Slope Factor
Hazard Quotient = CDD / Reference Dose

Description	Units	Value	Rationale (Source)
RME Concentration	*mg/L*	listed	*95% Upper Confidence Limit or Maximium Detect Value*
Ingestion rate	*L/d*	**1**	*Site Specific Parameter*
Exposure frequency	*d/y*	**250**	*Site Specific Parameter*
Exposure duration	*y*	**30**	*Site Specific Parameter*
Body weight	*kg*	**70**	*Adult body weight, Convention; (USEPA 1991)*
Averaging time	*d*	**25550**	*Carcinogenic effects; (USEPA 1989)*
Averaging time	*d*	**10950**	*Noncarcinogenic effects; (USEPA 1989)*

Contaminant (CT)	***Conc. mg/L***	***Lifetime Average Daily Dose mg/kg/d***	***Chronic Daily Dose mg/kg/d***	***Cancer Slope Factor CSFo kg·d/mg***	***Refernce Dose RfDo mg/kg/d***	***Lifetime Cancer Risk***	***Systemic Hazard Quotient***
Bromodichloromethane	4.78E-03	**2.01E-05**	**4.68E-05**	6.20E-02	2.00E-02	1.24E-06	9.36E-07
Chlorodibromomethane	1.07E-03	**4.48E-06**	**1.05E-05**	8.40E-02	2.00E-02	3.76E-07	2.09E-07
Chloroform	7.63E-02	**3.20E-04**	**7.46E-04**	6.10E-03	1.00E-02	1.95E-06	7.46E-06
Contaminant (RME)							
Bromodichloromethane	2.16E-02	**9.06E-05**	**2.11E-04**	6.20E-02	2.00E-02	5.62E-06	4.23E-06
Chlorodibromomethane	4.79E-03	**2.01E-05**	**4.69E-05**	8.40E-02	2.00E-02	1.69E-06	9.37E-07
Chloroform	1.74E-01	**7.30E-04**	**1.70E-03**	6.10E-03	1.00E-02	4.46E-06	1.70E-05

APPENDIX C

STATISTICAL ANALYSIS DATA

A summary of the statistical analysis is presented in the following tables. The tables presented are representative of all the data sets used for this HRA. Complete data sets are available upon request to AFIERA.

Human Health Risk Assessment
Pope Air Force Base (AMC)

D'Agostino's Test for Goodness of Fit (Sample Size >50)

Contaminant of Concern	Chloroform
Regulatory Exposure Limit	0 15
Units of recorded Data (e.g. ppm, mg/m3)	ug/L
Number of Samples	294
Significance Level (α)	0 05

D = 0 28114
s = 48.85826
Y = -0 54706

Totals		22429.37	1187277.735	701816.0457	2	1121.857989	-2.13607E-13	686.51387
Rank r	Plotting Position r/n	Data (Xi) ug/L	(i - .5(n+1))Xi	(Xi-M)^2	Modified Plotting for Yi	ln (Xi) Yi	Yi - M (ln)	(Yi-M)^2
1	0.003	0.25	-36.625	5782 138501	0 6137	-1.3863	-5 202	27.062
2	0 007	0.25	-36 375	5782 138501	0 6137	-1.3863	-5 202	27.062
3	0 010	0.25	-36.125	5782 138501	0 6137	-1.3863	-5 202	27.062
4	0.014	0.5	-71.750	5744 180814	1.3069	-0.6931	-4 509	20.331
5	0 017	0.5	-71 250	5744 180814	1 3069	-0 6931	-4 509	20 331
6	0 020	0.5	-70 750	5744 180814	1 3069	-0 6931	-4 509	20 331
7	0.024	0.5	-70.250	5744 180814	1 3069	-0.6931	-4 509	20.331
8	0 027	0.5	-69 750	5744 180814	1 3069	-0 6931	-4 509	20 331
9	0 031	0.5	-69 250	5744 180814	1 3069	-0 6931	-4 509	20.331
10	0 034	0.5	-68 750	5744 180814	1 3069	-0 6931	-4 509	20 331
11	0 037	0.5	-68 250	5744 180814	1 3069	-0 7	-4 509	20 331
12	0 041	0.5	-67 750	5744 180814	1 3069	-0 7	-4 509	20 331
13	0.044	0.5	-67.250	5744 180814	1 3069	-0.7	-4 509	20.331
14	0 048	0.5	-66 750	5744 180814	1 3069	-0 7	-4 509	20 331
15	0.051	0.5	-66.250	5744 180814	1 3069	-0.7	-4 509	20.331
16	0 054	0.5	-65 750	5744 180814	1 3069	-0 7	-4 509	20 331
17	0 058	0.5	-65 250	5744 180814	1 3069	-0 7	-4 509	20 331
18	0.061	0.5	-64.750	5744 180814	1.3069	-0.7	-4 509	20.331
19	0 065	0.5	-64 250	5744 180814	1 3069	-0 7	-4 509	20 331
20	0 068	0.5	-63 750	5744 180814	1 3069	-0 7	-4 509	20 331
21	0 071	0.5	-63 250	5744 180814	1 3069	-0 7	-4 509	20 331
22	0 075	0.5	-62 750	5744 180814	1 3069	-0 7	-4 509	20 331
23	0 078	1.25	-155 625	5631 057753	2 2231	0 2	-3 593	12 907
24	0.082	1.3	-160.550	5623 556215	2 2624	0.3	-3.553	12.627
25	0.085	1.3	-159 250	5623 556215	2 2624	0 3	-3 553	12.627
26	0 088	2	-243 000	5519 059691	2 6931	0.7	-3 123	9 751
27	0.092	4.9	-590.450	5096.585521	3 5892	1.6	-2 227	4.958
28	0.095	5.57	-665.615	5001.37132	3 7174	1.7	-2 098	4 403
29	0.099	5.9	-699.150	4954.804773	3.7750	1.8	-2 041	4.165
30	0 102	7.8	-916 500	4690 931351	4 0541	2.1	-1 762	3 104
31	0 105	9.7	-1130 050	4434 277929	4 2721	2 3	-1 544	2 383
32	0 109	11	-1270 500	4262 832957	4 3979	2 4	-1 418	2 011
33	0 112	11.4	-1305 300	4210 760657	4 4336	2 4	-1 382	1 911
34	0 116	12.8	-1452 800	4031 02761	4 5494	2 5	-1 266	1 604
35	0 119	13	-1462 500	4005 67146	4 5649	2 6	-1 251	1 565
36	0.122	13.2	-1471.800	3980 39531	4 5802	2.6	-1 236	1 527

Descriptive Analysis	
Mean (M)	76 29037415
Standard Error	3260.725251
Median	73 75
Mode	0 5
Standard Deviation	48 94156318
Sample Variance	2395.276606
Kurtosis	0.115740254
Skewness	0.492707273
Range	245.65
Minimum	0 25
Maximum	245 9
Sum	22429 37
Count	294
Confidence Level(95 0%)	0.178984323

P =	0.95
n =	294
Gamma = (g) =	0.95
z(gamma) =	1 645
z (P) =	1 645
k (g, P, n) =	1 674
t (P,df) = (P,n-1) =	0 063
Xp =	164.6
X(gamma) =	164.6

a =	1 - (z(gam)^2/2(n-1))	0.995383035
b =	z(P)^2 - (z(gamma)^2/n)	2 7

NORMAL				LOGNORMAL		
	Statistic Name	Xi	Yi	1 / ln Yi	Statistic Name	
ug/L	S = sample Std Dev =	48 942	1.531	4.62	= GS	[unitless]
ug/L	Mean = M =	76 290	3 816	#NUM!	= GM	ug/L
ug/L	M - S = X (16%)	27.349	2.285	9.83	= GX (16%)	ug/L
ug/L	M + S = X (84%)	125.232	5.347	209 88	= GX (84%)	ug/L
ug/L	M - t x S / (n^.5) = LCL =	76.111	3.810	45.16	= GLCL	ug/L
ug/L	M + t x S / (n^.5) = UCL =	76.470	3 821	45 67	= GUCL	ug/L
ug/L	M + Zp (95%) x S = X (95%)	156 799	6 334	563 32	= GX (95%)	ug/L
ug/L	M + k x S = UTL =	158.230	6.379	589.10	= GUTL	ug/L
ug/L	OEL =	0 15	0 15	0.15	= OEL	ug/L
ug/L	Median = Me =	73.75	4 30			
ug/L	(M - Me) / S =	0 052	-0 317			

Smaller Test Statistic, (M-Me)/S, implies better distribution Normal or Lognormal

For Normal Distribution, M = Me = Mo (mean = median = mode)

For Lognormal Distribution, mean = median = mode for [ln (data) in Nepers]

For Lognormal Distribution, Me of data = GM of data [in ppm or mg/m3 = ug/L]

Using Table A8, determine range base on α/2	α/2	0.025		0.975
	Range	-2.31984	-0.54706	1.53004

Conclude the best fit is Normal

Calculating the Concentration Term
(In accordance with EPA Supplemental Guidance to RAGS)

The concentration term has uncertainity associated with estmating the true average concentration at a site, therefore the 95 percent upper confidence limit (UCL) of the arithmetic mean should be used for this variable. Once calculated, this term will be used to calculate esitmated intake.

Obviously, with more data points, the higher the accuracy of the true mean. It is also important to consider transforming the data to the natural log (ln). Since our data is already transformed when fitting the data, both UCLs are calculated for us below.

Calculating the UCL of the Arithmetic Mean For a Lognormal Distribution

$$UCL = \exp(\ln(\Phi) + (Z_{val} \times S_y))$$

$$\Phi = y + 0.5 * Sy\text{^}2$$

Where:

UCL = upper confidence Limit
exp = e (constant (base of the natural log, equal to 2.718)) ra:
y = mean of the transformed data
S_y = standard deviation of the transformed data
ln = Natural Logarithm
n = number of samples

Calculating the UCL of the Arithmetic Mean For a Normal Distribution

$$UCL = m + 2 \times s$$

Where:

UCL = upper confidence Limit
m = mean of the untransformed data
s = standard deviation of the untransformed data

Φ	=	146.550	m	=	76.29
S_y	=	1.53	s	=	48.94
Y	=	3.816			
n	=	294			
$Z_{.95}$	=	1.645			

95 % UCL = 1817.786 ug/L

95 % UCL = 174.174 ug/L

Chloroform

Conclude the best fit is Normal -- Recommend Using the 95% UCL for a Normal Distributionas shown below:

95 % UCL = 174.174 ug/ L

* Note: The calculated 95% UCL is always the lowest value of the calculated value and max value.

D'Agostino's Test for Goodness of Fit (Sample Size >50)

Contaminant of Concern	Chloredbromomethane
Regulatory Exposure Limit	0.13
Units of recorded Data (e.g. ppm, mg/m3)	ug/L
Number of Samples	294
Significance Level (α)	0.05

D = 0.11009
s = 2.74117
Y = -98.35507

Totals		314.15	26084.225	2109.126471	2	-165.7820933	1.04095E-12	289.77484
Rank r	Plotting Position r/(n)	Data (Xi) ug/L	(i - .5(n+1))Xi	(Xi-M)^2	Modified Plotting for Yi	ln (Xi) Yi	Yi - M (ln)	(Yi-M)^2
1	0.003	0.25	-36.625	0.6700035	0.6137	-1.3863	-0.822	0.676
2	0.007	0.25	-36.375	0.6700035	0.6137	-1.3863	-0.822	0.676
3	0.010	0.25	-36.125	0.6700035	0.6137	-1.3863	-0.822	0.676
4	0.014	0.25	-35.875	0.6700035	0.6137	-1.3863	-0.822	0.676
5	0.017	0.25	-35.625	0.6700035	0.6137	-1.3863	-0.822	0.676
6	0.020	0.25	-35.375	0.6700035	0.6137	-1.3863	-0.822	0.676
7	0.024	0.25	-35.125	0.6700035	0.6137	-1.3863	-0.822	0.676
8	0.027	0.25	-34.875	0.6700035	0.6137	-1.3863	-0.822	0.676
9	0.031	0.25	-34.625	0.6700035	0.6137	-1.3863	-0.822	0.676
10	0.034	0.25	-34.375	0.6700035	0.6137	-1.3863	-0.822	0.676
11	0.037	0.25	-34.125	0.6700035	0.6137	-1.4	-0.822	0.676
12	0.041	0.25	-33.875	0.6700035	0.6137	-1.4	-0.822	0.676
13	0.044	0.25	-33.625	0.6700035	0.6137	-1.4	-0.822	0.676
14	0.048	0.25	-33.375	0.6700035	0.6137	-1.4	-0.822	0.676
15	0.051	0.25	-33.125	0.6700035	0.6137	-1.4	-0.822	0.676
16	0.054	0.25	-32.875	0.6700035	0.6137	-1.4	-0.822	0.676
17	0.058	0.25	-32.625	0.6700035	0.6137	-1.4	-0.822	0.676
18	0.061	0.25	-32.375	0.6700035	0.6137	-1.4	-0.822	0.676
19	0.065	0.25	-32.125	0.6700035	0.6137	-1.4	-0.822	0.676
20	0.068	0.25	-31.875	0.6700035	0.6137	-1.4	-0.822	0.676
21	0.071	0.25	-31.625	0.6700035	0.6137	-1.4	-0.822	0.676
22	0.075	0.25	-31.375	0.6700035	0.6137	-1.4	-0.822	0.676
23	0.078	0.25	-31.125	0.6700035	0.6137	-1.4	-0.822	0.676
24	0.082	0.25	-30.875	0.6700035	0.6137	-1.4	-0.822	0.676
25	0.085	0.25	-30.625	0.6700035	0.6137	-1.4	-0.822	0.676
26	0.088	0.25	-30.375	0.6700035	0.6137	-1.4	-0.822	0.676
27	0.092	0.25	-30.125	0.6700035	0.6137	-1.4	-0.822	0.676
28	0.095	0.25	-29.875	0.6700035	0.6137	-1.4	-0.822	0.676
29	0.099	0.25	-29.625	0.6700035	0.6137	-1.4	-0.822	0.676
30	0.102	0.25	-29.375	0.6700035	0.6137	-1.4	-0.822	0.676
31	0.105	0.25	-29.125	0.6700035	0.6137	-1.4	-0.822	0.676
32	0.109	0.25	-28.875	0.6700035	0.6137	-1.4	-0.822	0.676
33	0.112	0.25	-28.625	0.6700035	0.6137	-1.4	-0.822	0.676
34	0.116	0.25	-28.375	0.6700035	0.6137	-1.4	-0.822	0.676
35	0.119	0.25	-28.125	0.6700035	0.6137	-1.4	-0.822	0.676
36	0.122	0.25	-27.875	0.6700035	0.6137	-1.4	-0.822	0.676

Descriptive Analysis	
Mean (M)	1.068537415
Standard Error	38.0787558
Median	0.25
Mode	0.25
Standard Deviation	2.745847918
Sample Variance	7.539680789
Kurtosis	229.4332918
Skewness	14.28646783
Range	44.95
Minimum	0.25
Maximum	45.2
Sum	314.15
Count	294
Confidence Level(95.0%)	0.010041848

P =	0.95
n =	294
Gamma = (g) =	0.95
z(gamma) =	1.645
z (P) =	1.645
k (g, P, n) =	1.674
t (P,df) = (P,n-1) =	0.063
Xp =	2.5
X(gamma) =	2.5

a =	1 - (z(gam)^2/2(n-1))	0.995383035
b =	z(P)^2 - (z(gamma)^2/n)	2.7

NORMAL				LOGNORMAL	
	Statistic Name	Xi	Yi	1 / ln Yi	Statistic Name
ug/L	S = sample Std Dev =	2.746	0.994	2.70	= GS [unitless]
ug/L	Mean = M =	1.069	-0.564	0.57	= GM ug/L
ug/L	M - S = X (16%)	-1.677	-1.558	0.21	= GX (16%) ug/L
ug/L	M + S = X (84%)	3.814	0.431	1.54	= GX (84%) ug/L
ug/L	M - t x S / (n^.5) = LCL =	1.058	-0.568	0.57	= GLCL ug/L
ug/L	M + t x S / (n^.5) = UCL =	1.079	-0.560	0.57	= GUCL ug/L
ug/L	M + Zp (95%) x S = X (95%)	5.585	1.072	2.92	= GX (95%) ug/L
ug/L	M + k x S = UTL =	5.666	1.101	3.01	= GUTL ug/L
ug/L	OEL =	0.13	0.13	0.13	= OEL ug/L
ug/L	Median = Me =	0.25	-1.39		
ug/L	(M - Me) / S =	0.298	0.827		

Smaller Test Statistic, (M-Me)/S, implies better distribution: Normal or Lognormal

For Normal Distribution, M = Me = Mo (mean = median = mode)

For Lognormal Distribution, mean = median = mode for [ln (data) in Nepers]

For Lognormal Distribution, Me of data = GM of data [in ppm or mg/m3 = ug/L]

Using Table A8, determine range base on α/2

α/2	0.025		0.975
Range	-2.31984	-98.35507	1.53004

Conclude the best fit is Lognormal

Calculating the Concentration Term

(In accordance with EPA Supplemental Guidance to RAGS)

The concentration term has uncertainity associated with estmating the true average concentration at a site, therefore the 95 percent upper confidence limit (UCL) of the arithmetic mean should be used for this variable. Once calculated, this term will be used to calculate esitmated intake.

Obviously, with more data points, the higher the accuracy of the true mean. It is also important to consider transforming the data to the natural log (ln). Since our data is already transformed when fitting the data, both UCLs are calculated for us below.

Calculating the UCL of the Arithmetic Mean For a Lognormal Distribution

$$UCL = \exp(\ln(\varphi) + Z_{val}(Sy))$$

$$\varphi = y + 0.5 * Sy\text{^}2$$

Where:

UCL = upper confidence Limit
exp = e (constant (base of the natural log, equal to 2.718)) rasi
Y = mean of the transformed data
S_y = standard deviation of the transformed data
ln = Natural Logarithm
n = number of samples

φ =	0.9330
S_y =	0.99
Y =	-0.564
n =	294
$Z_{.95}$ =	1.645

95 % UCL =	4.790	ug/L

Calculating the UCL of the Arithmetic Mean For a Normal Distribution

$$UCL = m + 2 \times s$$

Where:

UCL = upper confidence Limit
m = mean of the untransformed data
s = standard deviation of the untransformed data

m =	1.07
s =	2.75

95 % UCL =	6.560	ug/L

Chlorodibromomethane

Conclude the best fit is Lognormal -- Recommend Using the 95% UCL for a Lognormal Distribution as shown below:

95 % UCL = 4.790 ug/L

* Note: The calculated 95% UCL is always the lowest value of the calculated value and max value.

D'Agostino's Test for Goodness of Fit (Sample Size >50)

Contaminant of Concern	Bromodichloromethane
Regulatory Exposure Limit	0.17
its of recorded Data (e.g. ppm, mg/m3)	ug/L
Number of Samples	294
Significance Level (α)	0.05

D = 0.13798
s = 7.12824
Y = -82.40666

Totals		1406.25	85014.825	14938.65916	2	353.4111811	-2.55795E-13	234.25093
Rank r	Plotting Position r/n	Data (Xi) ug/L	(i - .5(n+1))Xi	(Xi-M)^2	Modified Plotting for Yi	ln (Xi) Yi	Yi - M (ln)	(Yi-M)^2
1	0.003	0.25	-36.625	20.54956919	0.6137	-1.3863	-2.588	6.700
2	0.007	0.25	-36.375	20.54956919	0.6137	-1.3863	-2.588	6.700
3	0.010	0.25	-36.125	20.54956919	0.6137	-1.3863	-2.588	6.700
4	0.014	0.25	-35.875	20.54956919	0.6137	-1.3863	-2.588	6.700
5	0.017	0.25	-35.625	20.54956919	0.6137	-1.3863	-2.588	6.700
6	0.020	0.25	-35.375	20.54956919	0.6137	-1.3863	-2.588	6.700
7	0.024	0.25	-35.125	20.54956919	0.6137	-1.3863	-2.588	6.700
8	0.027	0.25	-34.875	20.54956919	0.6137	-1.3863	-2.588	6.700
9	0.031	0.25	-34.625	20.54956919	0.6137	-1.3863	-2.588	6.700
10	0.034	0.25	-34.375	20.54956919	0.6137	-1.3863	-2.588	6.700
11	0.037	0.25	-34.125	20.54956919	0.6137	-1.4	-2.588	6.700
12	0.041	0.25	-33.875	20.54956919	0.6137	-1.4	-2.588	6.700
13	0.044	0.5	-67.250	18.34548756	1.3069	-0.7	-1.895	3.592
14	0.048	0.5	-66.750	18.34548756	1.3069	-0.7	-1.895	3.592
15	0.051	0.5	-66.250	18.34548756	1.3069	-0.7	-1.895	3.592
16	0.054	0.5	-65.750	18.34548756	1.3069	-0.7	-1.895	3.592
17	0.058	0.5	-65.250	18.34548756	1.3069	-0.7	-1.895	3.592
18	0.061	0.5	-64.750	18.34548756	1.3069	-0.7	-1.895	3.592
19	0.065	0.5	-64.250	18.34548756	1.3069	-0.7	-1.895	3.592
20	0.068	0.5	-63.750	18.34548756	1.3069	-0.7	-1.895	3.592
21	0.071	0.5	-63.250	18.34548756	1.3069	-0.7	-1.895	3.592
22	0.075	0.5	-62.750	18.34548756	1.3069	-0.7	-1.895	3.592
23	0.078	0.5	-62.250	18.34548756	1.3069	-0.7	-1.895	3.592
24	0.082	0.8	-98.800	15.8655896	1.7769	-0.2	-1.425	2.031
25	0.085	1	-122.500	14.31232429	2.0000	0.0	-1.202	1.445
26	0.088	1	-121.500	14.31232429	2.0000	0.0	-1.202	1.445
27	0.092	1	-120.500	14.31232429	2.0000	0.0	-1.202	1.445
28	0.095	1	-119.500	14.31232429	2.0000	0.0	-1.202	1.445
29	0.099	1	-118.500	14.31232429	2.0000	0.0	-1.202	1.445
30	0.102	1	-117.500	14.31232429	2.0000	0.0	-1.202	1.445
31	0.105	1.1	-128.150	13.56569164	2.0953	0.1	-1.107	1.225
32	0.109	1.25	-144.375	12.48324266	2.2231	0.2	-0.979	0.958
33	0.112	1.25	-143.125	12.48324266	2.2231	0.2	-0.979	0.958
34	0.116	1.25	-141.875	12.48324266	2.2231	0.2	-0.979	0.958
35	0.119	1.25	-140.625	12.48324266	2.2231	0.2	-0.979	0.958
36	0.122	1.25	-139.375	12.48324266	2.2231	0.2	-0.979	0.958

Descriptive Analysis	
Mean (M)	4.783163265
Standard Error	241.7410676
Median	4
Mode	2.5
Standard Deviation	7.140391085
Sample Variance	50.98518484
Kurtosis	131.1124332
Skewness	10.4646285
Range	101.75
Minimum	0.25
Maximum	102
Sum	1406.25
Count	294
Confidence Level(95.0%)	0.026113144

P =	0.95
n =	294
Gamma = (g) =	0.95
z(gamma) =	1.645
z (P) =	1.645
k (g, P, n) =	1.674
t (P,df) = (P,n-1) =	0.063
Xp =	10.07
X(gamma) =	10.07

a =	1 - (z(gam)^2/2(n-1))	0.995383035
b =	z(P)^2 - (z(gamma)^2/n)	2.7

NORMAL				LOGNORMAL		
	Statistic Name	Xi	Yi	1 / ln Yi	Statistic Name	
ug/L	S = sample Std Dev =	7.140	0.894	2.45	= GS	[unitless]
ug/L	Mean = M =	4.783	1.202	3.33	= GM	ug/L
ug/L	M - S = X (16%)	-2.357	0.308	1.36	= GX (16%)	ug/L
ug/L	M + S = X (84%)	11.924	2.096	8.14	= GX (84%)	ug/L
ug/L	M - t x S / (n^.5) = LCL =	4.757	1.199	3.32	= GLCL	ug/L
ug/L	M + t x S / (n^.5) = UCL =	4.809	1.205	3.34	= GUCL	ug/L
ug/L	M + Zp (95%) x S = X (95%)	16.529	2.673	14.48	= GX (95%)	ug/L
ug/L	M + k x S = UTL =	16.738	2.699	14.87	= GUTL	ug/L
ug/L	OEL =	0.17	0.17	0.17	= OEL	ug/L
ug/L	Median = Me =	4.00	1.39			
ug/L	(M - Me) / S =	0.110	-0.206			

Smaller Test Statistic, (M-Me)/S, implies better distribution Normal or Lognormal

For Normal Distribution, M = Me = Mo (mean = median = mode)

For Lognormal Distribution, mean = median = mode for [ln (data) in Nepers]

For Lognormal Distribution, Me of data = GM of data [in ppm or mg/m3 = ug/L]

Using Table A8, determine range base on α/2

α/2	0.025		0.975
Range	-2.31984	-82.40666	1.53004

Conclude the best fit is Lognormal

Calculating the Concentration Term

(In accordance with EPA Supplemental Guidance to RAGS)

The concentration term has uncertainity associated with estmating the true average concentration at a site, therefore the 95 percent upper confidence limit (UCL) of the arithmetic mean should be used for this variable. Once calculated, this term will be used to calculate esitmated intake.

Obviously, with more data points, the higher the accuracy of the true mean. It is also important to consider transforming the data to the natural log (ln). Since our data is already transformed when fitting the data, both UCLs are calculated for us below.

Calculating the UCL of the Arithmetic Mean For a Lognormal Distribution

$$UCL = \exp(\ln(\varphi) + Z_{val}(Sy))$$

$$\varphi = y + 0.5 * Sy\text{^}2$$

Where:

UCL	=	upper confidence Limit
exp	=	e (constant (base of the natural log, equal to 2.718)) rais
Y	=	mean of the transformed data
S_y	=	standard deviation of the transformed data
ln	=	Natural Logarithm
n	=	number of samples

Calculating the UCL of the Arithmetic Mean For a Normal Distribution

$$UCL = m + 2 \times s$$

Where:

UCL	=	upper confidence Limit
m	=	mean of the untransformed data
s	=	standard deviation of the untransformed data

φ	=	4.9621	m	=	4.78
S_y	=	0.89	s	=	7.14
Y	=	1.202			
n	=	294			
$Z_{.95}$	=	1.645			
95 % UCL	=	21.600 ug/L	95 % UCL	=	19.064 ug/L

Bromodichloromethane

Conclude the best fit is Lognormal -- Recommend Using the 95% UCL for a Lognormal Distribution as shown below:

95 % UCL = 21.600 ug/L

* Note: The calculated 95% UCL is always the lowest value of the calculated value and max value.